Adaptive Gain Control in the Auditory System

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The principle of adaptive coding in sensory neurons is widely accepted, although outstanding questions remain. One concerns the extent to which adaptive coding constitute an emergent property of a particular level of processing, or is inherited from neurons upstream - quantifying the relative contributions of these components for any one level of processing can be difficult as relatively few stimulus parameters exist that do not influence processing at the very earliest stages of a sensory system. Another concerns the extent to which adaptive coding constitutes a means for improving behavioural performance *per se*. Here, I report adaptive coding of inferior colliculus (IC) neurons in anaesthetized guinea pigs to interaural time differences (ITDs) - small differences in the timing of a sound at the two ears used to determine azimuthal location of a sound. ITDs are first processed in the medial superior olive (MSO) of the brainstem, making them particularly suited for determining the site at which central adaptive mechanisms might arise - contributions below the first stage of binaural integration can be excluded. Stimuli consisted of interaurally-delayed white noise of 5s duration (noise seed and ITD sequence randomized across 75 repeats). ITDs were restricted to the maximum physiological range of the guinea pig (±330µs), and randomly chosen every 50ms from a defined distribution, with a high-probability region (HPR), from which ITDs were selected with probability = 0.8. Responses were obtained for 5 HPRs centred at 0, ±132 and ±264µs. Both single neurons and the population demonstrated some adjustment in coding accuracy to ipsilateral-leading sounds, suggesting improvement of coding accuracy (as assessed by Fisher Information, FI) to stimulus statistics of naturally-encountered ITDs. Nevertheless, this adjustment was broad (essentially hemispheric) and markedly less than that recently demonstrated for sound intensity in the same brain region. Although peak FI coincided with the centre of the HPR when the HPR was centred at zero, this was not the case for the more lateral HPRs, and ITDs were not necessarily most accurately processed when presented as part of a HPR. Several reasons can be posited to account for the relatively small effects observed. First, adaptive gain control may require more than a single (MSO to IC) synaptic stage to emerge. Second, responses to changing HPRs were often multiplicative; regardless of the statistical distribution, rate-vs-ITD functions often rose from a common location on the ITD axis rather than showing lateral shifts to follow the HPR. This multiplicative/divisive effect is similar to that observed when GABA-ergic inhibition is locally blocked/applied to ITD-sensitive IC neurons, and does not necessarily provide for an increase in FI, since response variance normally increases with rate. Related to this, response variability often decreased markedly (Fano factors <<1.0) with increasing rate, despite IC neurons being assumed to show Poisson spiking statistics. Combined, these factors appear to favour high FI for ITDs relatively close to the midline (i.e. sound sources located frontally) regardless of the statistical distribution of ITDs. In this regard, it should be noted that a sound heard to one side or the other often elicits a rapid orienting response, with the interaural cues resetting to zero as the head swiftly moves to face the presumed location of the source. Thus, the relative failure of peak FI to follow the stimulus distribution of ITDs may be the result of mechanisms specialized to maximize spatial information in frontal space when a sound is heard in any location, rather than a failure to adapt to ITD *per se*. The relative importance of frontal space was confirmed by psychophysical investigation; ITD discrimination thresholds improved, and false alarm rates decreased, when sounds with ITDs at or close to zero were preceded by adapting sounds (1-2s duration) with ITDs of 0 or ±400µs. In contrast, discrimination thresholds for sounds with ITDs close to ±400µs were largely unaffected, and could be worse, when preceded by adapting sounds, regardless of the ITD of the adaptor.